Pioneers

11. Edwin Howard Armstrong (1890-1954): genius of radio

W.A. ATHERTON

"Seldom can an inventor look philosophically upon the bane of his existence, patent litigation, and find much good therein" – Armstrong, 1942.

No doubt there are some around, but I have never met an undergraduate who has made a major invention. Yet E.H. Armstrong did just that whilst a student at Columbia University in New York. He went on to make at least two other great electronic inventions. They brought him fame, fortune – and patent misery.

Edwin Howard Armstrong was born in New York City on December 18, 1890, the son of John and Emily Armstrong. His father ran the American branch of the Oxford University Press and when his son was about 14 years old he gave him a copy of The Boy's Book of Inventions. It was then, it is said, that the boy announced his intention of becoming an inventor.

Whatever the truth of that, Armstrong's attention had certainly been gripped by Marconi's adventures with radiotelegraphy. The attic of the family home in Yonkers became littered with electrical components as Armstrong began to teach himself about radio.

At Columbia University, an establishment with which he was to have a long connection, he was fortunate to study under Professor Michael Pupin, who had patented the loading coil used in long-distance telegraphy and telephony.

Armstrong graduated in 1913 and became an assistant teacher at Columbia, so continuing his association with Pupin. By then he had already made the first of his great inventions: the regenerative or feedback circuit.

POSITIVE FEEDBACK

The first electronic valve was the vacuum diode. It was invented in 1904 in England by J.A. Fleming and was used as a radio-wave detector. A couple of years later in America Lee de Forest added a third electrode (the grid) to make the triode, or, as he called it, the audion. Of course the triode became immensely important, but in its early years it was just another radio-wave detector and not even the best. In a legal wrangle in 1912 it was described as worthless.

In 1912-13 Armstrong studied the uses of the triode. He discovered that if part of the anode output was fed back to reinforce (regenerate) the input at the grid then the whole circuit became a very good amplifier as well as a detector.

If even more current was fed back then the circuit oscillated and could be used for generating a sinewave carrier for radio or telephony. Its inventor was soon known as "Feedback Armstrong".

This discovery was one of the birth pangs of electronics and its patent rights were of immense value.

Unfortunately for Armstrong, others had made the same discovery – in particular Lee de Forest, who had just sold telephone repeater rights to the triode amplifier for $50,000. Later he sold the radio receiver rights for $90,000. Further claimants to the invention of the regenerative circuit were Irving Langmuir of General Electric in the USA and Alexander Meissner in Germany.

Armstrong was to discover that making and keeping inventions is a far more complex business than was portrayed in The Boy's Book of Inventions.

Aged only 22, he was slow to patent his invention and he soon found himself in a legal battle with de Forest which was to last 20 years and to cost a fortune. One commentator bewailed the money spent on lawyers which could have been better invested in electronics.

The American Institute of Radio Engineers (IRE) awarded him its Medal of Honor in 1917. When the Supreme Court eventually found in favour of de Forest in 1934, Armstrong offered to return the medal. But the IRE reaffirmed the award: in its members' eyes Armstrong was the true inventor, whatever the courts said.

Shortly before his death Armstrong gave $50,000 to Columbia University for a research project on the success and failure of law courts in deciding complex technical matters. Patent disputes were the bane of his life.

THE SUPERHET

When America entered the First World War, Armstrong became an Army Signals Corps officer and was sent to France. There he pondered the gunnery problem of how to locate enemy aircraft. The solution seemed to lie in detecting the high-frequency radiation emitted by the aircraft's ignition system. But how could such high frequencies be amplified?

The heterodyne (or mixing) principle was well established, having been invented by R.A. Fessenden in 1905. Armstrong decided to heterodyne the received signal twice, first to an inaudible intermediate frequency which could be amplified, then to a lower audible frequency. He called the circuit the superheterodyne, now more usually abbreviated to superhet. Though it was not in fact used to locate aircraft, it improved the stability and sensitivity of radio receivers and

enabled them to be tuned to a wide range of frequencies. It became the continuing basis of most radio reception.

Armstrong patented the superhet in 1920. It was indisputably his own invention, and this time there were no patent challenges. He sold the patents for the superhet, and for his regenerative and other circuits, to Westinghouse in 1920 for over $335,000. Some of that money was needed to pay debts to lawyers. Looking back on the deal one has to say that Westinghouse got a bargain, even though Armstrong retained the royalties earned from amateur use.

SUPER-REGENERATION

The following year he applied for a patent on his next invention – super-regeneration. This was a method of defeating the main problem of the regenerative circuit which was its tendency to burst into unwanted oscillation. This time the patent was snapped up by the Radio Corporation of America (RCA), whose general manager was still smarting from the previous Westinghouse coup on the superhet. The deal gave Armstrong a large block of RCA shares and made him a millionaire.

Ironically, RCA did better commercially from a patent exchange agreement with Westinghouse which gave it access to the superhet patent.

Meanwhile Armstrong the millionaire had become a married man, having taken the RCA boss's secretary as his bride. He did very well all round from the RCA deal!

FREQUENCY MODULATION

Whilst the court cases with de Forest still dogged him, Armstrong somehow found the time and energy to make one more amazing radio invention, frequency modulation.

One problem that had plagued radio from its earliest days was 'static'. Static appears as a variation in the amplitude of the received signal and so any amplitude modulation (a.m.) receiver is prone to static interference. It was natural for radio engineers to try to reduce this interference. Many had tried and failed. Pupin had summed up the problem: "God gave men radio and the devil made static".

With Pupin, Armstrong had studied the matter as early as 1914. In the early twenties he called it a terrific problem, "the only one I ever encountered that, approached from any direction, always seems to be a stone wall".

In 1933 he surmounted that wall, acquired four new patents and opened a Pandora's Box of new tribulations which eventually drove him to suicide.

Yet frequency modulation (f.m.) was not new. It had been studied in 1902 and again in the 1920s but it was usually treated in a manner not unlike a.m. The bandwidth was kept as narrow as possible so as to restrict the passage of interference whilst still letting through the signal. Used in that way, f.m. was felt to have little to offer and was discarded. Mathematical investigations had dubbed it totally useless.

Armstrong's eventual answer was to step outside the existing state of the art and go the other way. In his own words, "The invention of the f.m. system gave a reduction of interfering noises of hundreds or thousands of times. It did so by proceeding in exactly the opposite direction that mathematical theory had demonstrated one ought to go to reduce interference. It widened instead of narrowed the band".

Armstrong himself paid for the construction of a transmitter and receiver. A demonstration was given in November 1935 at a frequency of 110MHz. The signal-to-noise ratio of around 100:1 was a lot better than the 30:1 of the best a.m. stations.

Then the troubles began. The US radio industry showed little interest. New transmitters and more expensive receivers would be needed. It was alleged that f.m. would not work beyound the horizon and that a.m. would be as good if the same high frequencies were used.

Armstrong offered the new system to RCA, which refused it and instead announced an intention to pursue electronic television, which would compete for the same frequency bands.

Armstrong had a stubborn streak. He sold a block of his shares and withdrew to go it alone. Using his own money he built his own station outside New York City. In July, 1939 he went on the air and proved that f.m. radio really did work and was superior in quality to a.m. radio.

An ally was found in a New England network which was suffering badly from static. F.m. broadcasting began to take off.

By January 1940, some 150 applications had began made to operate f.m. stations and 20 were either on the air or nearing completion. Westinghouse, General Electric and Zenith were among the companies queuing up for licences to make receivers and to meet Armstrong's condition of paying a royalty on each one. RCA offered a $1 million single payment with no royalties. Armstrong refused.

Then came more problems. World War Two delayed everything. At its end the Federal Communications Commission moved f.m. radio broadcasting to a new frequency band and restricted transmitter power to one tenth of the pre-war level. Over 50 f.m. transmitters and half a million receivers became obsolete.

Meanwhile RCA refused to recognise Armstrong's patents, depriving him of further fame and fortune. Smaller companies followed big brother's lead.

Armstrong began legal proceedings against RCA in 1948. More years of court battles loomed ahead. Five years later a further 20 actions were begun against other manufacturers whilst the RCA case was still far from settled.

Suddenly it was all too much. On a cold night at the end of January 1954 he put on his overcoat and jumped from the window of his 13th floor apartment in New York. It was a terrible indictment of the treatment meted out by parts of the radio industry to one of its greatest inventors.

Sixteen months later in Britain, the BBC began broadcasting a high-quality f.m. radio service.

Across the Atlantic, Armstrong's widow, Marion, rejected legal advice and fought on. She settled with RCA for the same million dollars her husband had rejected and used the money to fight the rest.

Thirteen years after his death it was finished. Ten million dollars of outstanding royalties and settlements were received. Armstrong was vindicated.

Next in this series of pioneers of electrical communication will be Jack S. Kilby, the man who made the first integrated circuit.

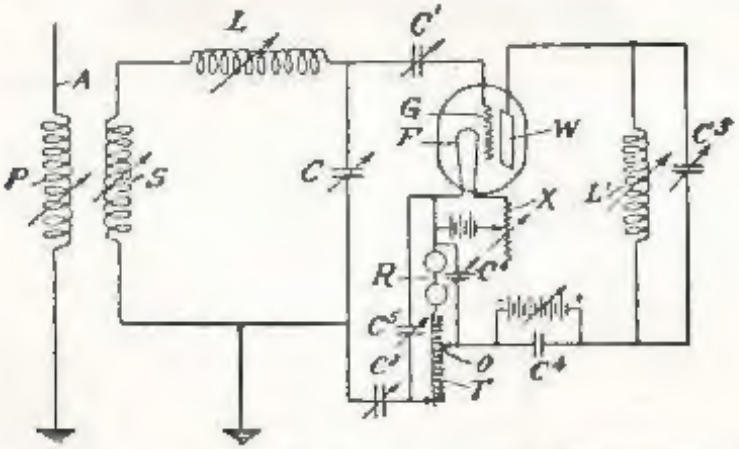

Fig.1. Armstrong's regenerative circuit, from the patent of 1912. Note the unfamiliar symbol for the triode.

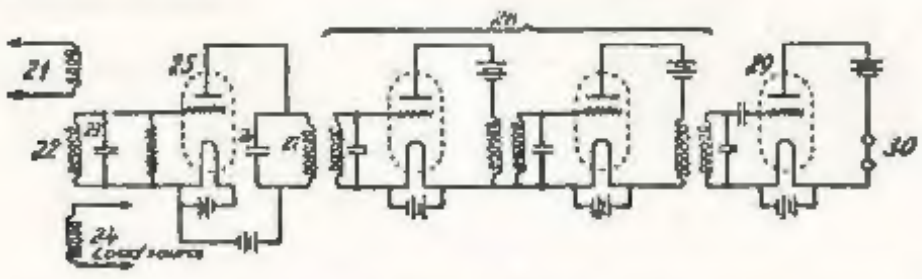

Fig.2. The superhet from the 1920 patent – mixer, i.f. amplifier, detector and audio amplifier. The legend at bottom left identifies the local oscillator injection point.